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EFFICACY OF VINEGAR (ACETIC ACID) AS AN ORGANIC HERBICIDE

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EFFICACY OF VINEGAR (ACETIC ACID) AS AN ORGANIC HERBICIDE
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ABSTRACT

Greenhouse studies to evaluate the potential of acetic acid as a non-selective and selective herbicide indicated that pelargonic acid may have potential as a non-selective herbicide as it provided control of both broadleaf and grass species. Pine oil extract had more activity on mustard than oat, however, both species were controlled at high rates. Acetic acid had more activity on broadleaf species than grass species, indicating some potential for broadleaf weed control in cereals.
Other greenhouse studies found that nozzle orientation and/or adjuvant could result in slightly higher levels of mustard control, but had little effect on green foxtail control.
Since acetic acid exhibited some selectivity in the greenhouse, it was hypothesized that vinegar may have value as a selective herbicide in cereal crops. Spring wheat exhibited tolerance to vinegar; however, oat yields declined with increasing vinegar rate. High application values (800 to 1600 L ha) of vinegar (10% acetic acid) were required to provide adequate weed control in spring wheat. Optimum wheat yields were achieved at application volumes of 1300 to 1400 L ha. Acetic acid does not appear to be cost-effective, as the cost would range from $600 to $1200/ha ($250.00 to $500.00/acre).
A study conducted at the Kernen Research Farm in Saskatoon indicates that flax did not tolerate acetic acid at rates required to control weeds.
A field study conducted at Scott and Saskatoon to evaluate the efficacy of pelargonic acid as a non-selective herbicide. Pelargonic acid did not provide satisfactory control of tame oat. Higher than label rates were required to control oriental mustard and tame buckwheat. The cost of controlling these weeds with pelargonic acid would be $325 to $650 per ha based on 2004 conditions, therefore, it is not a cost-effective alternative. Abstract prepared by Khalid Iftikhar.

Potential of Acetic Acid, Pelargonic Acid and Pine Extract as "Organic Herbicides" (Greenhouse Studies)

Introduction

- In 2001, Saskatchewan had 773 certified organic farms, the highest number in Canada.
- Organic weed control methods involve cultural and mechanical practices which often do not provide adequate control and cause soil erosion or moisture loss. A post-emergence spray could help address these problems.
- Acetic acid is currently sold as a non-selective herbicide for domestic use in North America.
- Pine extract (Interceptor™) a certified herbicide approved for organic use in New Zealand.
- Pelargonic acid (Scythe®) is also called nonanoic acid and is sold in the United States.

Objectives

to study the efficacy of pine oil, pelargonic acid, and acec acid as foliar weed control agents on indicator species using dose response analysis.

- to identify application parameters that maximize weed control efficacy.

Materials and Methods

Three lab studies were conducted to investigate the potential of pine oil (Interceptor™), pelargonic acid (Scythe®) and acetic acid (vinegar) for the control of broadleaf and grassy species and to identify the application parameters that maximize weed control efficacy.

Active Ingredient Specifications

Vinegar was mixed to three concentrations (20, 10 and 5% v/v) from 100% glacial acetic acid, (Fisher Scientific) and applied in volumes ranging from 50 to 2000 L/ha.

- Interceptor (680 g/L pine oil, other ingredients unknown, Organic Interceptor Products, New Zealand), was mixed to three concentrations (16.6% - label recommendation, 10 and 5% v/v) and applied in volumes ranging from 50 to 2000 L/ha.
- Scythe (57% pelargonic acid, 3% "related fatty acids" (C6-C12), 40% "inert ingredients" (petroleum distillates), Mycogen Corporation), was mixed to two concentrations (3 and 6% v/v, label recommendations) and applied in volumes ranging from 50 to 1600 L/ha.

Plant species:

Calibre tame oat (*Avena sativa*) and AC Vulcan oriental mustard (*Brassica juncea*) were grassy and broadleaf indicator species used.

- Seedlings were grown in greenhouses at the Saskatoon Research Station under fluorescent light and a day-length of 19 hours, average day temperatures of 20°C and average night temperatures of 15°C. Relative humidity (RH) was maintained between 50%-80%. Plants were hand watered every morning with an overhead spray nozzle and monitored throughout the day to prevent soil desiccation.

Spray Method & Assessment

- Plants were sprayed in a cabinet sprayer at various application volumes (Table 1). The cabinet sprayer was operated at a pressure of 30 psi and a boom height of 53 cm. Dose was achieved by varying the concentration and carrier volume (Table 2).

Table 1: Spray parameters: nozzle size, cabinet sprayer speed as determined by carrier volume.

Carrier Volume (L/ha)	Tee Jet Nozzle Size	Cabinet Sprayer Speed (km/h)
50	XR8001	2.83
100	XR8001	1.97
200	XR8002	2.49
400	XR8004	2.57

800	XR8004	1.40
1200	XR8004	0.96
1600	XR8004	0.73
2000	XR8004	0.59

Table 2: Dose calculation table for acetic acid

Concentration of Active Ingredient (v/v)	Water Volume (L/ha)							
	50	100	200	400	800	1200	1600	2000
5%	2.5	5	10	20	40	60	80	100
10%	5	10	20	40	80	120	160	200
20%	10	20	40	80	160	240	320	400

- Tame oat was sprayed at two leaf stages: small (1 leaf stage) and large (2-3 leaf stage). Oriental mustard was sprayed at two leaf stages: small (0.5-1 leaf stage) and large (1-2 leaf stage).
- Species and growth stage effects were combined as a single species variable. Each experiment was a randomized complete block design (RCBD) with 4-6 replicates per treatment depending on plant availability.

Data Collection

- When plant symptoms were fully developed (usually 5 to 10 DAT), control was visually rated using a 0-100 scale where 0 = no control and 100 = plant death. Symptoms included stunting, chlorosis and necrosis. Fresh weight (above ground shoot biomass) was determined by clipping plants at ground level and weighing immediately.

- All data were analysed by analysis of variance (ANOVA) using Statistica v. 5.5 to determine the main effects (plant species, application volume or product concentration) and interactions that governed weed control. Dose effects were evaluated by dose response modeling using the following equation:

$$\mathbf{y} = C + ((D - C) / (1 + \mathbf{x} / I)^{b})$$

where $\mathbf{y}$ = fresh weight or percent control
C = lower limit of response
D = upper limit of response
$\mathbf{x}$ = dose (herbicide concentration x application volume)
$I = GR_{50}$ (dose giving 50% reduction in fresh weight)
b = slope at GR_{50}

- Although experiments were conducted using various concentrations and carrier volumes, the overall herbicide active ingredient (ai) dose was derived from the total of application volume and concentration. This enabled a direct comparison for each of the three herbicides and the relative effectiveness of each concentration.

Results and Discussion

Pine Oil (Interceptor ™)

- Analysis of variance indicated that all effects and interactions were statistically significant (Table 3). Carrier volumes were highly significant ($p<0.01$) indicating that different volumes of pine oil provided differing levels of control. The two different concentrations provided highly significant ($p<0.01$) results, indicating that control depended on concentration. Species reacted significantly different ($p<0.01$) to changes in concentration. The species X volume interaction ($p<0.01$) was highly significant indicating that species response differed with carrier volume. Concentration X volume was highly significant ($p<0.01$) indicating that the effect of carrier volume depended on herbicide concentration. The volume effect depended on concentration and species and thus dose response was evaluated separately for both mustard and oats (Figures 1 & 2).

- Oriental mustard was more susceptible to pine oil than was tame oat (Figures 1 & 2).

Table 3: Analysis of variance for tame oat and oriental mustard treated with 5 and 10% pine oil (plant fresh weight)

Source	p-value
Rep	<0.001
Species	<0.001
Volume	<0.001
Concentration	<0.001
Species x Volume	<0.001
Concentration x Volume	0.001
Species x Volume x Concentration	0.049

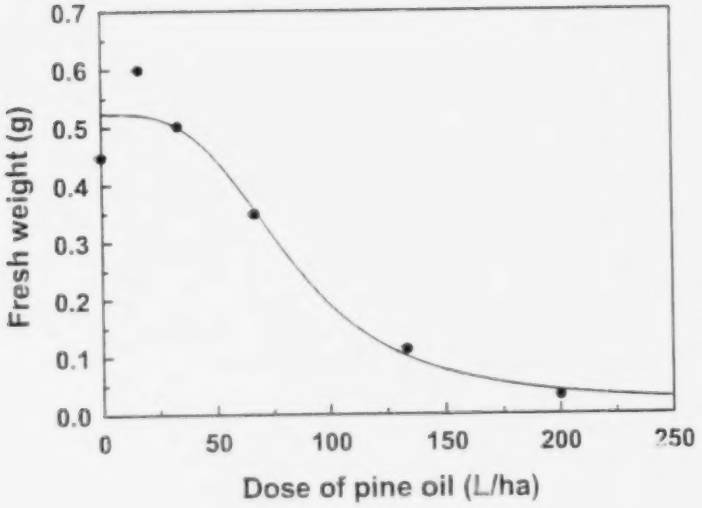


Figure 1: Dose response for tame oat treated with pine oil.

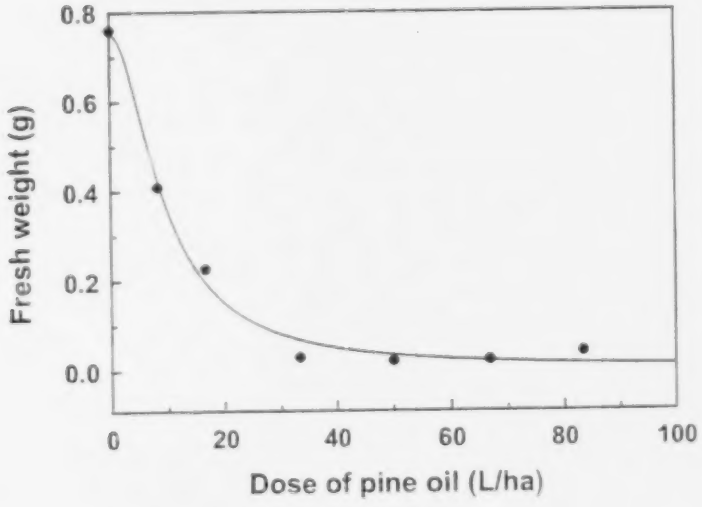


Figure 2: Dose response for oriental mustard treated with pine oil.

- On small mustard, 5% pine oil was as effective as the 17% concentration (Figure 3). Although differences in pine oil concentration did not greatly affect relative potency for small mustard, higher concentrations (17%) tended to be slightly more effective on large mustard. Oat control with pine oil was variable in some cases, but low (5%) concentrations were more effective than either 10% or 17% concentration, regardless of leaf stage.

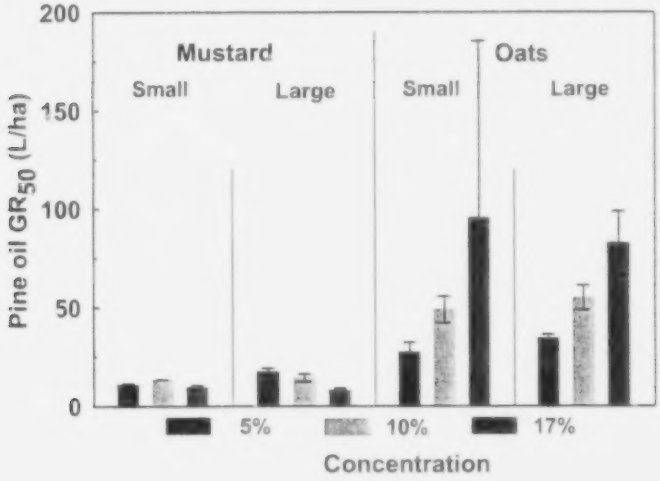


Figure 3: Relative potency of pine oil applied at three concentrations to tame oat and oriental mustard. Lower GR_{50} values represent better control.

- GR_{50} values were useful when comparing herbicides and plant species (Table 4). The GR_{50} value is the dose (L/ha) of active ingredient (pine oil) required to reduce fresh weight by 50%. For 5, 10 and 17% pine oil concentrations on large mustard, GR_{50} values were 17.4 L/ha, 14.3 L/ha and 8.0 L/ha, respectively (Table 4). GR_{50} values for small mustard were 9.4 L/ha, 13.4 L/ha and 10.7 L/ha for 5, 10 and 17% concentrations, respectively. Relative potency was similar for small and large oat plants. GR_{50} values were 27.3 L/ha, 48.9 L/ha and 95.6 L/ha and 34.5 L/ha, 54.9 L/ha and 82.6 L/ha for small and large oat, respectively.

Table 4: GR_{50} values for tame oat and oriental mustard treated with three concentrations of pine oil.

Pine oil Concentration (%)	GR_{50} (L/ha of pine oil)			
	Oriental Mustard		Tame Oat	
	Small	Large	Small	Large
5%	9.4	17.4	27.3	34.5
10%	13.4	14.3	48.9	54.9
17%	10.7	8.0	95.6	82.6

Pelargonic Acid (Scythe®)

- Analysis of variance (Table 5) indicated the effect of plant species was highly significant ($p<0.01$); response to pelargonic acid varied between tame oat and oriental mustard. The effect of carrier volume was highly significant ($p<0.01$) indicating that different amounts of pelargonic acid provided differing levels of control. The two concentrations differed significantly ($p<0.01$). Species reacted differently ($p<0.01$) to changes in concentration. The species X volume interaction ($p<0.01$) was highly significant indicating that species response differed with carrier volume. Concentration X volume was highly significant ($p<0.01$) indicating that the effect of carrier volume depended on herbicide concentration. The volume effect depended on concentration and species and thus dose response was evaluated separately for both mustard and oats (Figures 4 & 5).

Table 5: Analysis of variance for tame oat and oriental mustard treated with 3% and 6% pelargonic acid (plant fresh weight)

Source	p-value
Rep	0.665
Species	< 0.001
Volume	< 0.001
Concentration	< 0.001
Species x Concentration	< 0.001
Species x Volume	< 0.001
Concentration x Volume	< 0.001
Species x Volume x Concentration	< 0.001

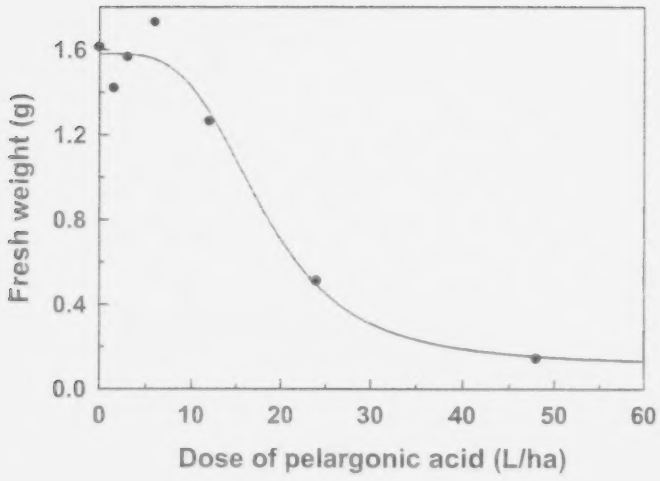


Figure 4: Dose response for tame oat treated with pelargonic acid.

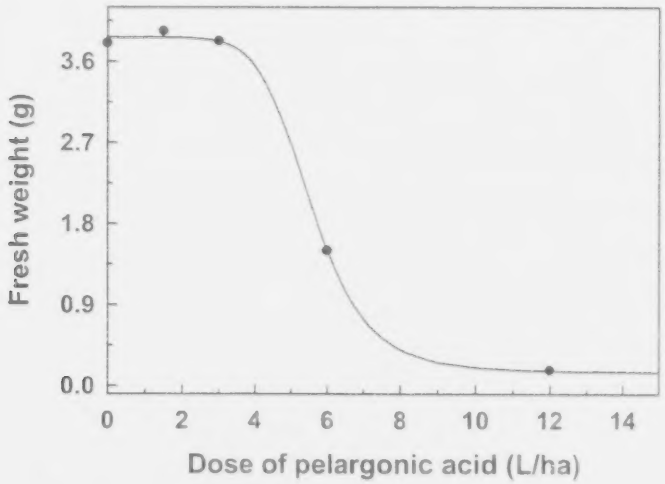


Figure 5: Dose response for oriental mustard treated with pelargonic acid.

- Like pine oil, pelargonic acid was more injurious to oriental mustard than to tame oat (Fig. 6 & Table 6) but on the whole, required lower doses. Relative potency was similar with 3 and 6% for both large and small mustard. For small mustard, GR_{50} values were 2.2 and 1.8 L/ha for 3 and

6% concentrations, respectively. The GR_{50} values for large mustard were 3.0 and 1.5 L/ha respectively (Table 6).

- Oat required higher doses but there was little difference between 3 and 6% concentration for either leaf stage. For small oats, GR_{50} values were 9.1 and 9.2 L/ha for 3 and 6% concentrations, respectively (Table 6). The GR_{50} values for large oats were 15.4 and 13.5 L/ha respectively (Table 6).

Table 6: GR_{50} values for tame oat and oriental mustard treated with two concentrations of pelargonic acid.

Pelargonic acid concentration (%)	(GR_{50}) Relative Potency (L/ha pelargonic acid)			
	Oriental Mustard		Tame Oat	
	Small	Large	Small	Large
3%	2.2	3.0	9.1	15.4
6%	1.8	1.5	9.2	13.5

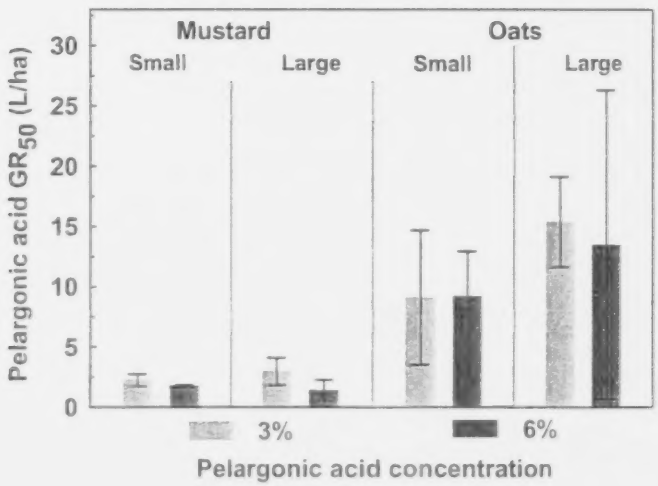


Figure 6. Relative potency of pelargonic acid applied at two concentrations to tame oat and oriental mustard. Lower GR_{50} values represent better control.

Acetic Acid

Tame Oat and Oriental Mustard Treated with 10% Acetic Acid

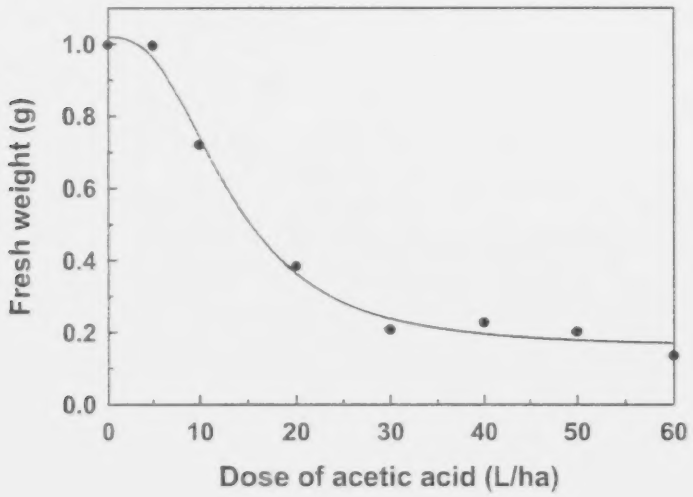
- Analysis of variance (Table 7) indicated the effect of species was not significant ($p > 0.05$); oats and mustard had similar fresh weights. Carrier volumes were highly significant ($p<0.01$) indicating that different amounts of acetic acid provided different levels of control. The species x volume interaction ($p <0.01$) was highly significant indicating that the response to acetic acid was

dependant on the species.

Table 7: Analysis of variance for tame oat and oriental mustard treated with 10% acetic acid.

Source	p-value
Rep	0.011
Species	0.227
Volume	<0.001
Species x Volume	<0.001

- Results were therefore used to compute a dose response curve for oriental mustard (Fig. 7) based on non-linear regression; however the lack of response in tame oat data did not generate a normal regression curve (Fig. 8).



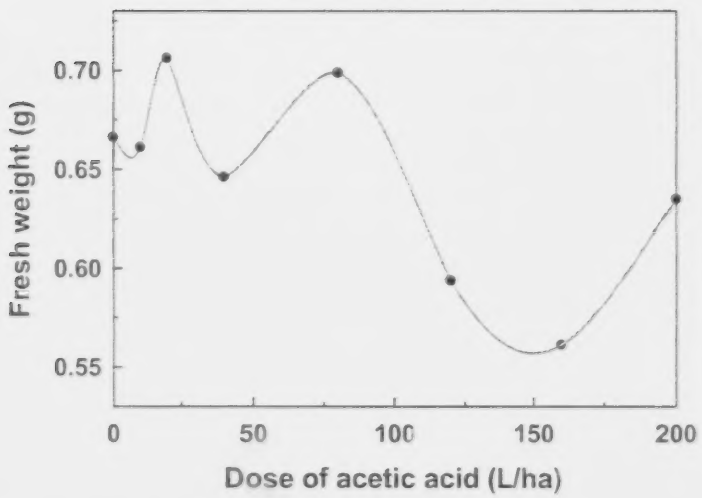


Figure 7: Dose response for oriental mustard treated with 10% acetic acid.

Figure 8: Dose response for tame oat treated with 10% acetic acid.

- Seventy-one percent control of tame oat was achieved with volumes in excess of 2000 L/ha when 10% acetic acid was sprayed from a bottle in a drench application (sb) (Fig. 9). The GR_{50} value for oriental mustard treated with 10% acetic acid was 21.3 L/ha (Table 9).

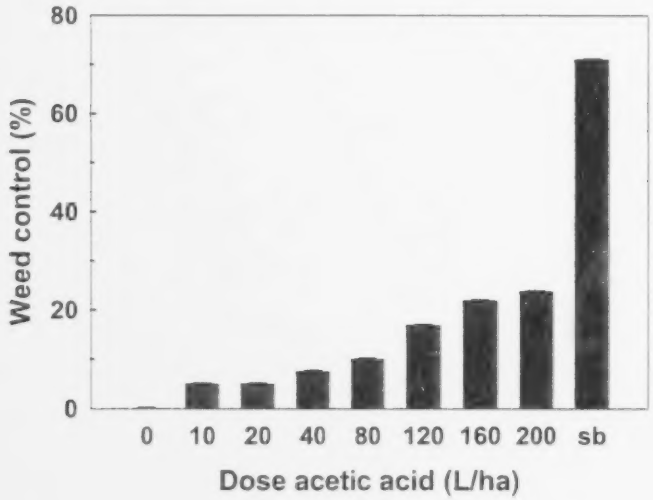


Figure 9: Weed control of tame oat treated with 10% acetic acid. Error bars represent standard error. 'sb' = spray bottle drench treatment

Oriental Mustard Treated with 5, 10 & 20% Acetic Acid

- Because oriental mustard was susceptible to acetic acid, an additional study investigated the effects of three different concentrations of acetic acid (5, 10 & 20%). Analysis of variance (Table 8) indicated the effect of plant size was highly significant ($p<0.01$); response to acetic acid varied between large and small mustard plants. The effect of carrier volume and concentration were highly significant ($p<0.01$) indicating that different concentrations of acetic acid provided differing levels of control. Small plants reacted differently than large plants to changes in concentration. The size x volume interaction ($p<0.01$) was highly significant indicating that the response to acetic acid was dependant on the size of the mustard plants. Concentration x volume was highly significant ($p<0.01$) indicating that the volume response depended on acetic acid concentration.

Table 8: Analysis of variance for oriental mustard treated with 5, 10 & 20 % acetic acid

Effect	p-value
Rep	<0.001
Size	<0.001

Volume	<0.001
Concentration	<0.001
Size x Concentration	<0.001
Size x Volume	<0.001
Concentration x Volume	<0.001
Size x Concentration x Volume	0.325

- Lower concentrations of acetic acid were more effective at controlling small mustard but higher concentrations were best suited for large mustard (Fig. 10 & Table 9). The GR_{50} values for small mustard were 11.9 L/ha, 14.6 L/ha and 20.3 L/ha for 5, 10 and 20% concentrations. For large mustard, GR_{50} values were 28.3, 19.9 and 9.5 L/ha, for the respective three concentrations.

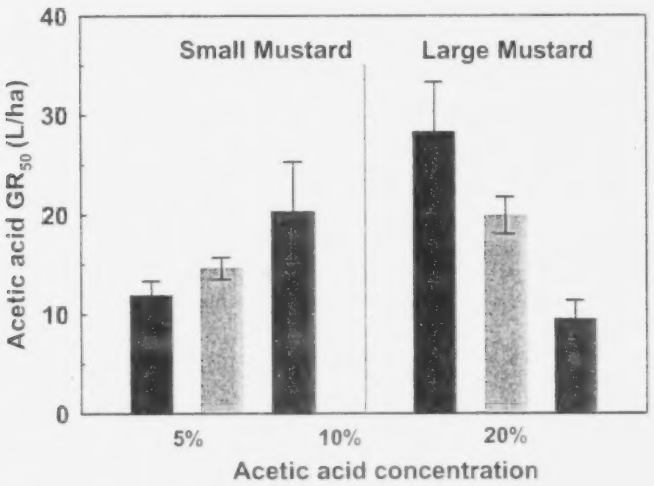


Figure 10: Relative potency of acetic acid applied at three concentrations to oriental mustard. Lower GR_{50} values represent better control.

Table 9: GR_{50} values for oriental mustard treated with three concentrations of acetic acid.

Acetic Acid Concentration (%)	(GR_{50}) Relative Potency (L/ha acetic acid)	
	Sm Mustard	Lg Mustard
5%	11.9	28.3
10%	14.6	19.9
20%	20.3	9.5

Potential for Selective Broadleaf Weed Control in Cereals

- At low doses, the pine oil extract was more effective on mustard than oats indicating some potential for selective weed control (Fig. 11). However, at high doses, the pine oil extract provided a fairly high degree of oat control. Pelargonic acid was able to provide control of both mustard and oat; although mustard was more sensitive (Fig. 12). Acetic acid effectively controlled mustard, but had little effect on oat, indicating potential for selective weed control of broadleaf weeds in cereal crops (Fig. 13). Pelargonic acid appears to have more potential as a non-selective herbicide than the pine oil extract or acetic acid.

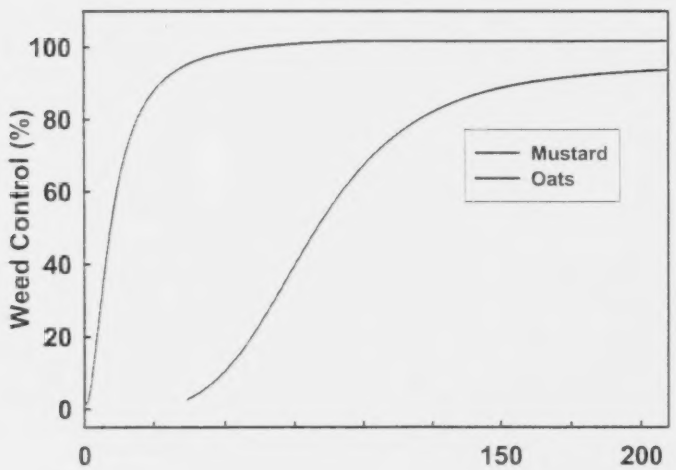


Figure 11: The effect of active ingredient dose of pine oil on control of tame oat and oriental mustard.

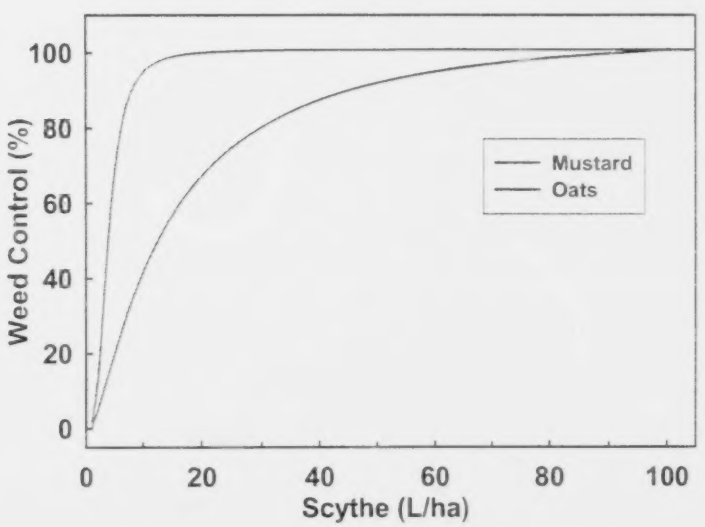


Figure 12: The effect of active ingredient dose of pelargonic acid on control of tame oat and oriental mustard.

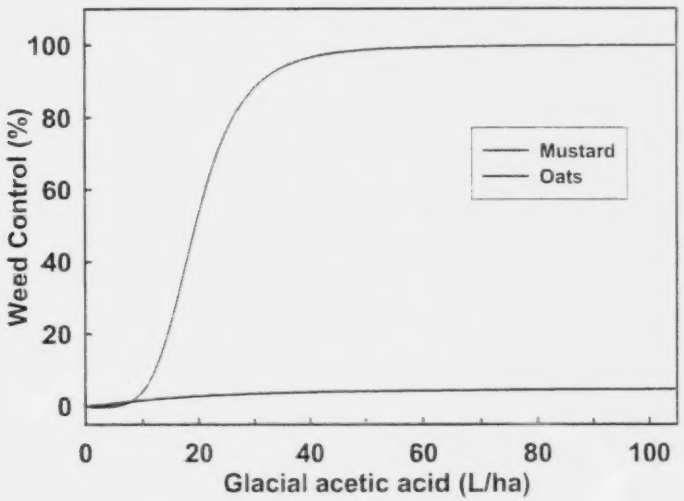


Figure 13: The effect of active ingredient dose of acetic acid on control of oriental mustard and tame oat.

Conclusions

- For all three herbicides, lower doses were required to control small weeds compared to larger weeds.
- Interceptor™ was effective at controlling both tame mustard and oats at high doses. However, at low doses, there may be potential for selective control of mustard in cereals.
- Scythe® was an effective non-selective herbicide on both mustard and oats.
- Acetic acid controlled mustard but had little effect on oat; indicating potential for selective weed control of broadleaf species in cereal crops.

Efficacy of Acetic Acid for the Control of Horticultural Weeds (Greenhouse Study)

Background

- Objective: determine the efficacy of 10% acetic acid on four weed species common to horticultural production systems.

Materials and Methods

- Species included stinkweed (*Thlapsi arvense*), redroot pigweed (*Amaranthus retroflexus*),

portulaca (*Portulaca oleraceae*), round leaf mallow (*Malva rotundifolia*) and oriental mustard (*Brassica juncea*).

- Seedlings were grown in greenhouses at the Saskatoon Research Station under fluorescent light and a day-length of 19 hours, average day temperatures of 20°C and average night temperatures of 15°C. Relative humidity (RH) was maintained between 50%-80%. Plants were hand watered every morning with an overhead spray nozzle and monitored throughout the day to prevent soil desiccation.
- One concentration of acetic acid (10%), prepared from 100% glacial acetic acid was applied to the seedlings. Seedlings were sprayed in seven carrier volumes ranging from 100 to 2000 L/ha. An eighth treatment saturated plants with 10% acetic acid via a hand-held spray bottle, similar to a home garden application.
- Application timing: oriental mustard: 1-2 leaf stage; stinkweed: 5-6 leaf stage; redroot pigweed: 2- leaf stage; portulaca: 2-5 leaf stage; and round leaf mallow: 1-2 leaf stage.

Data collection

- When plant symptoms were fully developed (usually five to ten DAT), control was visually rated using a 0-100 scale where 0 = no control and 100 = plant death. Symptoms were stunting, chlorosis and necrosis. Fresh weight (above ground shoot biomass) was determined by clipping plants at ground level and weighing immediately.
- All data were analysed using analysis of variance (ANOVA) using Statistica v. 5.5 to determine the main effects (plant species, application volume or product concentration) and interactions that governed weed control. Dose effects were evaluated by dose response modeling (using the following equation:

$$\mathbf{y} = C + ((D - C) / (1 + \mathbf{x} / I)^{b})$$

where $\mathbf{y}$ = fresh weight or percent control
C = lower limit of response
D = upper limit of response
$\mathbf{x}$ = dose (herbicide concentration x application volume)
$I = GR_{50}$ (dose giving 50% reduction in fresh weight)
b = slope at GR_{50}

Results

- All plants showed signs of wilting within an hour of treatment. With the exception of stinkweed, turgor did not return. Necrotic lesions (death) developed within a few hours after spraying. Injury symptoms were primarily necrosis and leaf curling where the spray contacted the leaf tissue.

Stinkweed and Redroot Pigweed

- Analysis of variance (Table 1) indicated the effect of species was highly significant ($p<0.01$). Volume was highly significant ($p < 0.01$) indicating that different volumes of vinegar provided different levels of weed control. The species x volume interaction ($p<0.01$) indicated that the response to acetic acid was dependant on the species. Dose response curves were therefore generated for both stinkweed and pigweed (Fig. 2 and 3).

Table 1: Analysis of variance for stinkweed and red root pigweed treated with 10% acetic acid

Source	p-value
Rep	0.057
Species	<0.001
Volume	<0.001
Species x Volume	<0.001

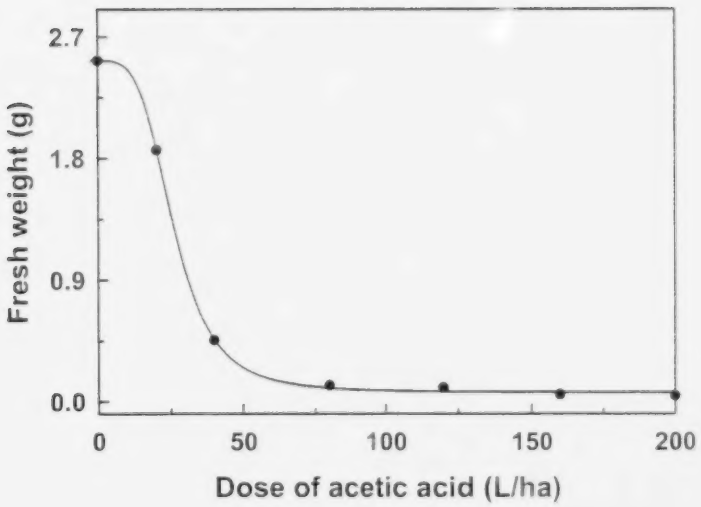


Figure 1: Dose response for stinkweed treated with 10% acetic acid.

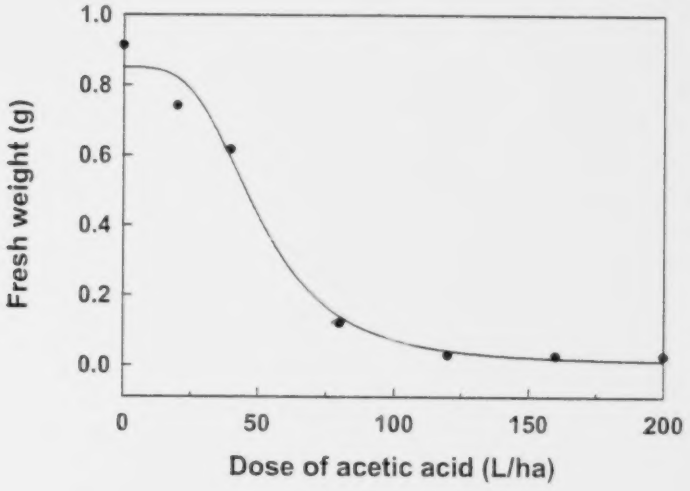


Figure 2: Dose response for red root pigweed treated with 10% acetic acid.

Portulaca

- Analysis of variance (Table 2) indicated the volume effect was significant ($p<0.05$). However, on closer analysis, portulaca responded like tame oat, and did not generate a typical response curve. Only the hand-held drench application provided control of portulaca (100%) (Figure 3).

Table 2: Analysis of variance for portulaca treated with 10% acetic acid.

Source	p-value
Rep	0.757
Volume	0.005

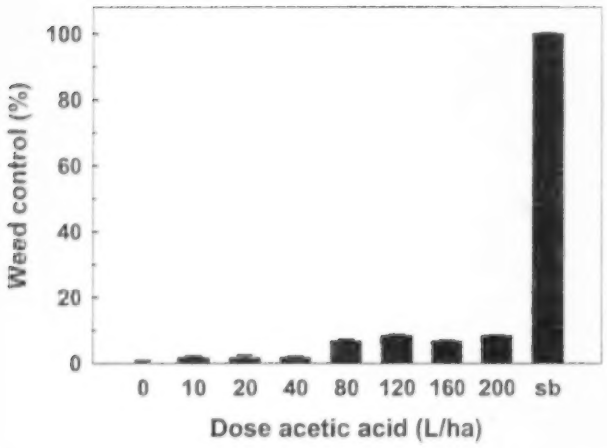


Figure 3: Effect of 10% acetic acid dose on control of portulaca. Error bars represent standard error. 'sb' = spray bottle drench treatment.

Round Leaf Mallow

- Analysis of variance (Table 3) indicated that volume was highly significant ($p<0.01$) for round leaf mallow. A dose response was therefore calculated for round leaf mallow (Figure 4).

Table 3: Analysis of variance for round-leaf mallow treated with 10% acetic acid

Effect	p-value
Rep	<0.005
Volume	<0.001

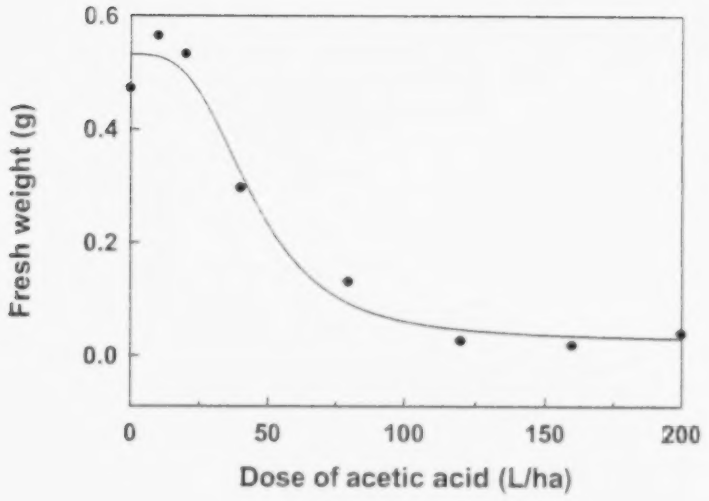


Figure 4. Dose response for round-leaf mallow treated with 10% acetic acid

- Results for all weed species treated with 10% acetic acid were used to compute regression equations to provide an indication of their relative susceptibility to acetic acid (Table 4). Portulaca was tolerant to acetic acid. Redroot pigweed required the highest volume of active ingredient at 50.1 L/ha acetic acid, followed by round-leaf mallow (44.4 L/ha), stinkweed (25.9 L/ha) and oriental mustard (21.3 L/ha).

Table 4. Regression equations for five plant species treated with acetic acid.

Plant Species	Regression equation y = C + ((D – C) / (1 + x / I) ^b)	GR_{50} (L/ha acetic acid)
stinkweed	y=(0.068)+(((2.522)-(0.068))/(1+(x/25.936))^(3.828)	25.9
redroot pigweed	y=(0.007)+(((0.850)-(0.007))/(1+(x/50.121))^(3.597)	50.1
oriental mustard	y=(0.075)+(((1.479)-(0.075))/(1+(x/21.287))^(4.492)	21.3
portulaca	no curve	n/a
round leaf mallow	y=(0.028)+(((0.532)-(0.028))/(1+(x/44.437))^(3.249)	44.4

Conclusions

- The relative susceptibility of five broadleaf plant species to acetic acid was portulaca > redroot pigweed > round-leaf mallow > stinkweed > oriental mustard.

Effect of Nozzle Angle and Adjuvants on Control of Tame Mustard and Green Foxtail (Greenhouse Study)

Background

- Greenhouse studies conducted at AAFC, Saskatoon indicated that acetic acid effectively controlled mustard, a broadleaf species, but was less effective on a grass species (tame oat). The objective of this study was to determine whether setting the nozzles forward at a 45° angle would improve coverage and thus improve the efficacy of acetic acid, particularly on grassy species. The second objective was to determine whether adjuvants would improve acetic acid efficacy.

Materials and Methods

- 10% acetic acid was applied to green foxtail and tame mustard at the 3-5 and 1-leaf stage, respectively. Acetic acid was applied in a carrier volume of 200 L ha^{-1}. Treatments are outlined in Table 1. Agral 90 is a non-ionic surfactant commonly used with many herbicides. EKOL is a canola based oil surfactant manufactured in the Czech Republic.

Table 1: Spray nozzle and adjuvant treatments.

Treatment	Adjuvent	Angle
1	None	vertical
2	None	forward
3	Agral 90	Vertical
4	Agral 90	forward
5	Ekol	Vertical
6	Ekol	forward
7	Control	Control

Results

- Nozzle angle and adjuvants improved control of green foxtail slightly (Fig. 1); however, the level of control was not satisfactory. A forward orientation of the nozzles and surfactants improved the efficacy on tame mustard (Fig. 1); however, there was no additive effect from the treatments. Based on experiments previously reported, an application volume of 200 L ha^{-1} is not sufficient to provide satisfactory control of most plant species. Therefore, future studies should evaluate the potential of adjuvants over a broader range of application volumes.

Conclusions

- Nozzle angle and adjuvants improved the control of mustard with acetic acid but had little impact on the control of green foxtail. More research is required to evaluate the potential for adjuvants to improve the efficacy of acetic acid over a broad range of application volumes.

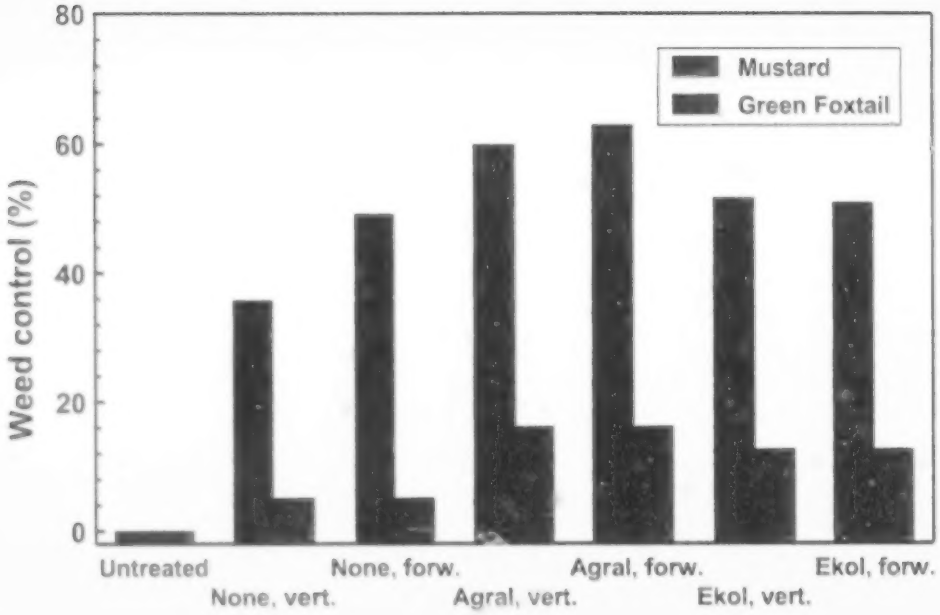


Figure 1: Effect of adjuvant and nozzle angle on control of mustard and green foxtail with 10% acetic acid. Saskatoon. 2003.

Vinegar for Pre-seed and Post-emergence Control of Broadleaf Weeds in Spring Wheat (Field Study, Scoot 2003-04)

Background

Research conducted by the USDA indicated that vinegar at acetic acid concentrations of 10 to 20% provided good control of some annual and perennial weed species. It was hypothesized that vinegar may be a potential non-selective herbicide option for pre-seed or pre-emergence weed control in organic crops. Greenhouse studies at the Saskatoon Research Center indicated that grass weeds were more tolerant to vinegar than broadleaf weeds. Thus, field studies were conducted at the Scott Research Farm in 2003 and 2004 to investigate the efficacy of a pre-seed application of vinegar as well as the potential for selective broadleaf weed control in spring wheat.

Objectives:

- To determine whether vinegar can provide an acceptable alternative to tillage in organic systems as a pre-seed burn-off and to selectively control broadleaf weeds in a cereal crop.

Materials and Methods

- The 2004 study area contained a non-uniform natural population of common lambs-quarters (*Chenopodium album* L.)
- The 2003 study area contained a high natural population of winter annual weeds, in particular shepherd's-purse (*Capsella bursa-pastoris* (L.) Medik.).
- Pre-seed treatments: Vinegar (10% acetic acid) at 0, 200, 400, 800, 1600 and 2400 L ha^{-1} and glyphosate at 450 g ai ha^{-1} (commercial standard). Applications were made three days prior to seeding spring wheat.
- Spring wheat (cv. Eatonia) was seeded at a rate of 90 kg ha-1 in 22 cm rows on May 13, 2003 and May 28, 2004. Wild mustard (*Sinapis arvensis* L.) and cow cockle (*Viccaria hispanica* (Mill.) Rauschert) were seeded between the crop rows at a uniform density.
- Post-emergence treatments: Vinegar (10% acetic acid) at 0, 200, 400, 800, 1600 and 2400 L ha^{-1} and bromoxynil-MCPA at 560 g ai ha^{-1} (commercial standard). Application timing: wheat - 1 to 2 leaf stage; broadleaf weeds - cotyledon to 1-leaf stage.
- Visual ratings of the pre-seed application were done 3, 6 and 10 DAT while ratings of the post-emergence application were done 3, 6, and 28 DAT (2004) and 3, 6, 19, and 28 DAT in 2003. Total weed biomass and crop yield data was also collected.

Results

Pre-seed:

2004 results

- Acetic acid provided between 0 and 65% control of common lambs-quarters pre-seed (data not shown). However, the population was quite variable and difficult to rate. Since some plots had very high densities while others had few, it was decided to overspray the entire area with glyphosate at 450 g ai ha^{-1}. This was done to reduce confounding effects for rating post-emergence applications.

2003 results

- Pre-seed application of 10% acetic acid vinegar resulted in over 80% control of shepherd's purse at application volumes of 1600 L ha^{-1} or higher (Fig. 1). Injury symptoms appeared quickly (within 1 to 3 days).

Post-emergence

Wheat Tolerance

- Visual injury to wheat was less in 2004 than 2003 (Fig. 2). In both years, rates of 800 L ha^{-1} or higher caused initial wheat injury but recovery occurred with little visible injury 28 DAT (Fig. 2).

Weed Control

- In 2004, in-crop application volumes of acetic acid at 600 L ha^{-1} or higher resulted in greater than 80% control of wild mustard and cow cockle (Figs. 3 and 4). In 2003, application volumes of acetic acid at 800 L ha^{-1} or higher resulted in greater than 80% control of wild mustard and cow cockle (Figs. 3 and 4); however, some regrowth was evident at the 800 L ha^{-1} rate.
- In 2004, weed biomass was relatively low and none of the acetic acid treatments resulted in a significant reduction in weed biomass (Fig. 5). In 2003, weed biomass was reduced by 60% and 90% of volumes of 800 and > or = 1600 L ha^{-1}, respectively (Fig. 5).
- In 2003, dandelions present in the study were not uniform in all replicates to rate. However, application volumes of 2400 L ha^{-1} were unable to control dandelion. Significant injury occurred on the outer leaves; however, complete recovery occurred within two to three weeks.

Wheat Yields

- In 2004, highest wheat yields were attained at 1600 L ha^{-1} and they were equal to the commercial standard (Fig. 6). However, an application volume of 800 L ha^{-1} resulted in statistically higher yields than the check. In 2003, highest wheat yields were attained at 800 L ha^{-1}(Fig. 6); however, an application volume of 400 L ha^{-1} resulted in a significant yield response that was comparable to the commercial standard. Initial injury to the weeds from the 400 L ha^{-1} rate may have provided a competitive advantage to the spring wheat, even though long-term weed control at this volume would be considered unsatisfactory.
- When the yield data was combined over the two years, a second-order polynomial regression equation was fitted to the data which explained > 90% of the variability (Fig. 7). From the regression analysis, it would indicate that wheat yields were maximized at acetic acid application volumes of 1300 to 1400 L ha^{-1} (Fig. 7).

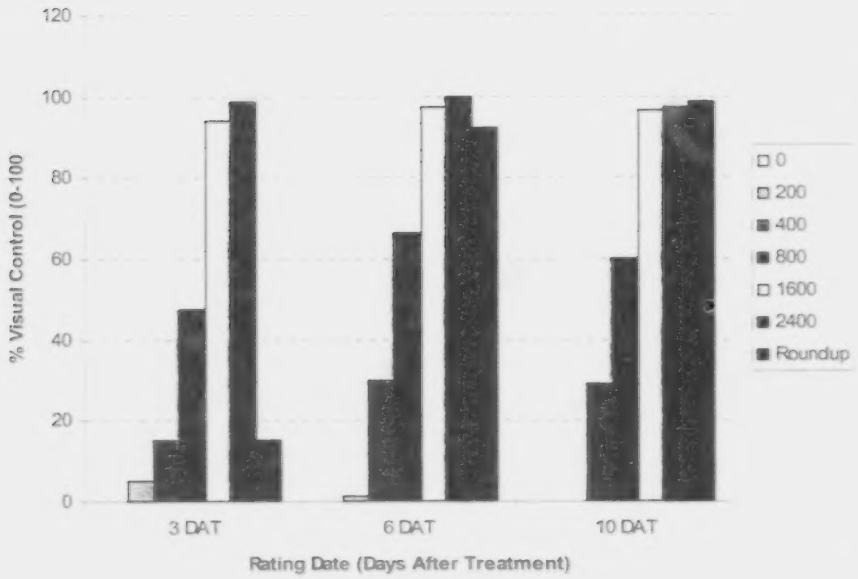


Figure 1: Effect of pre-seed vinegar (10% acetic acid) application on control of shepherd's purse. Scott 2003.

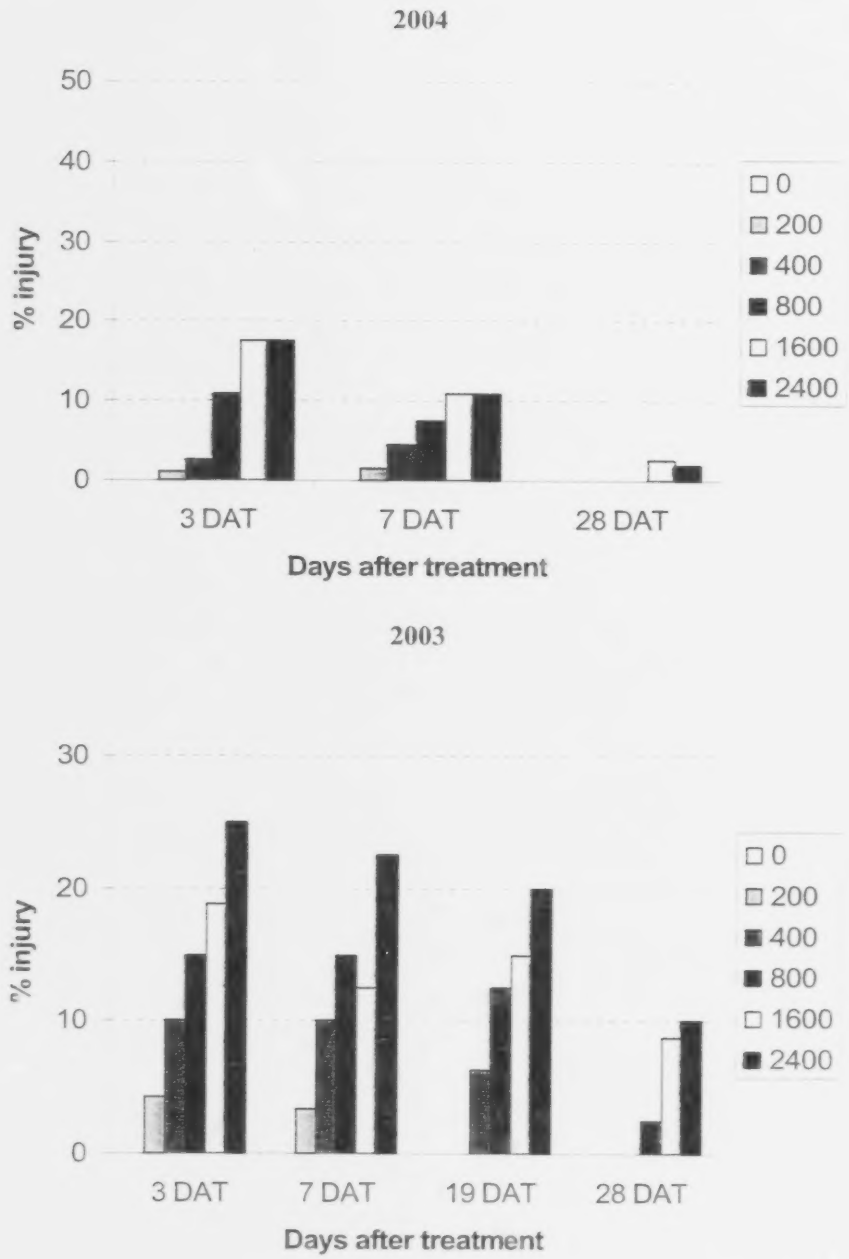


Figure 2: Tolerance of spring wheat to post-emergence (10% acetic acid) application at volumes of 200 to 2400 L ha-1 at Scott in 2004 (above) and 2003 (below).

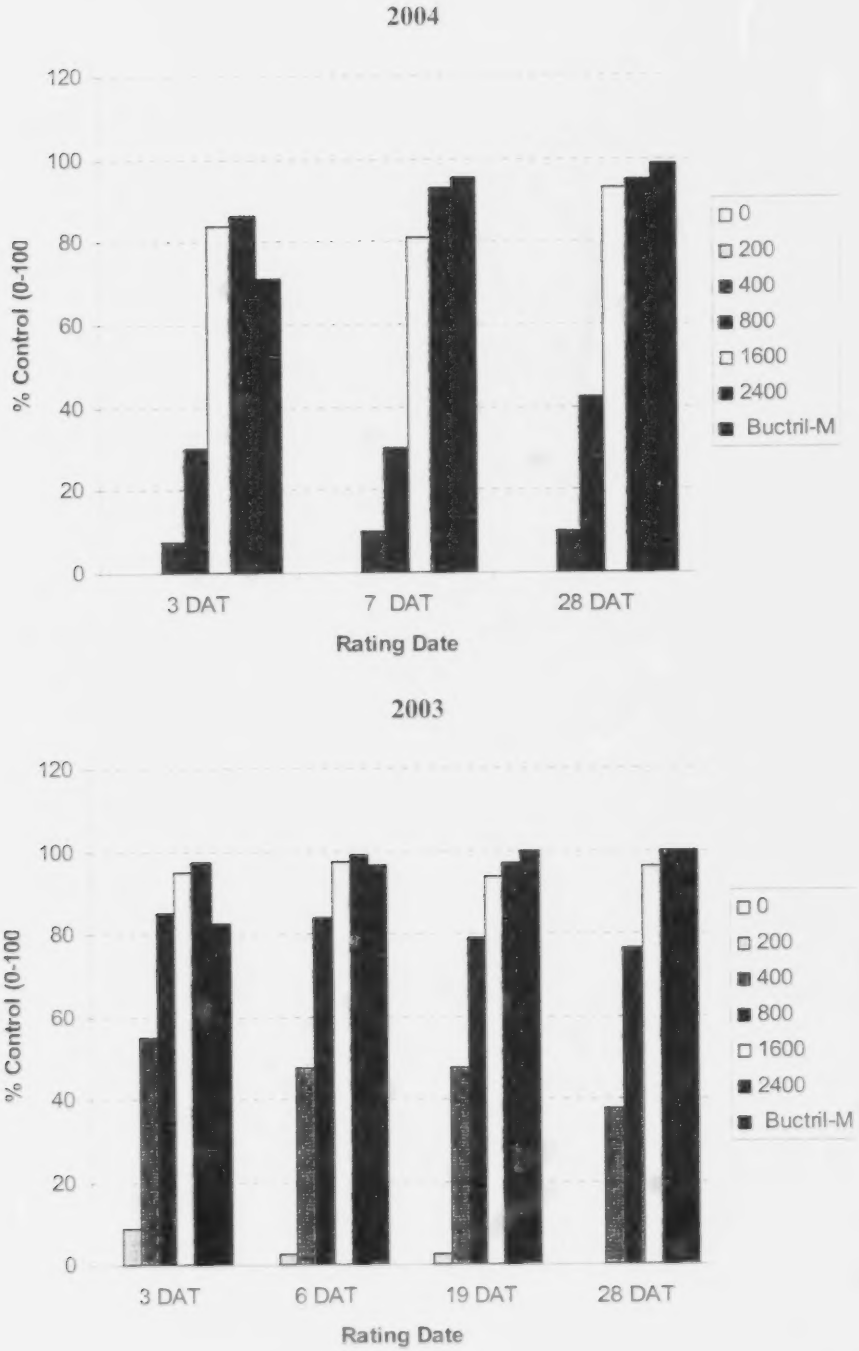


Figure 3: Effect of post-emergence vinegar (10% acetic acid) application on control of wild mustard in spring wheat at Scott in 2004 (above) and 2003 (below).

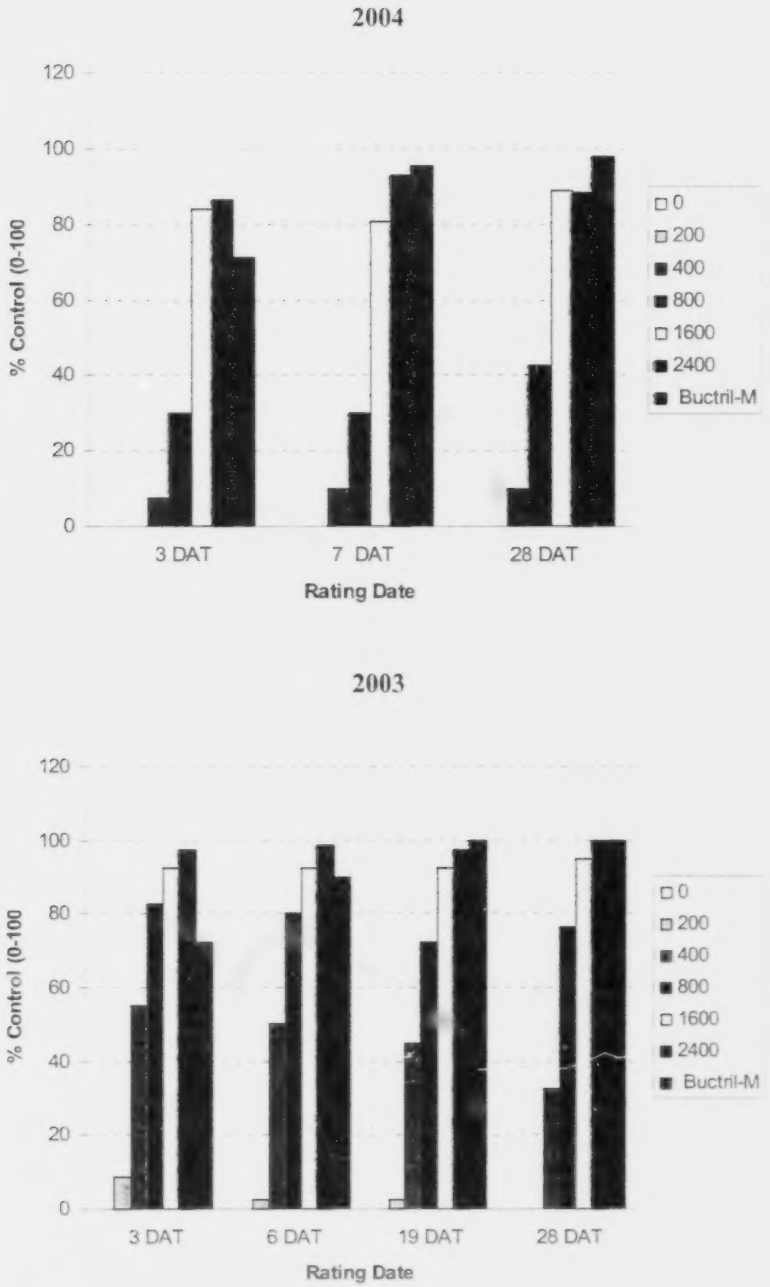


Figure 3: Effect of post-emergence vinegar (10% acetic acid) application on control of cow cockle in spring wheat at Scott in 2004 (above) and 2003 (below).

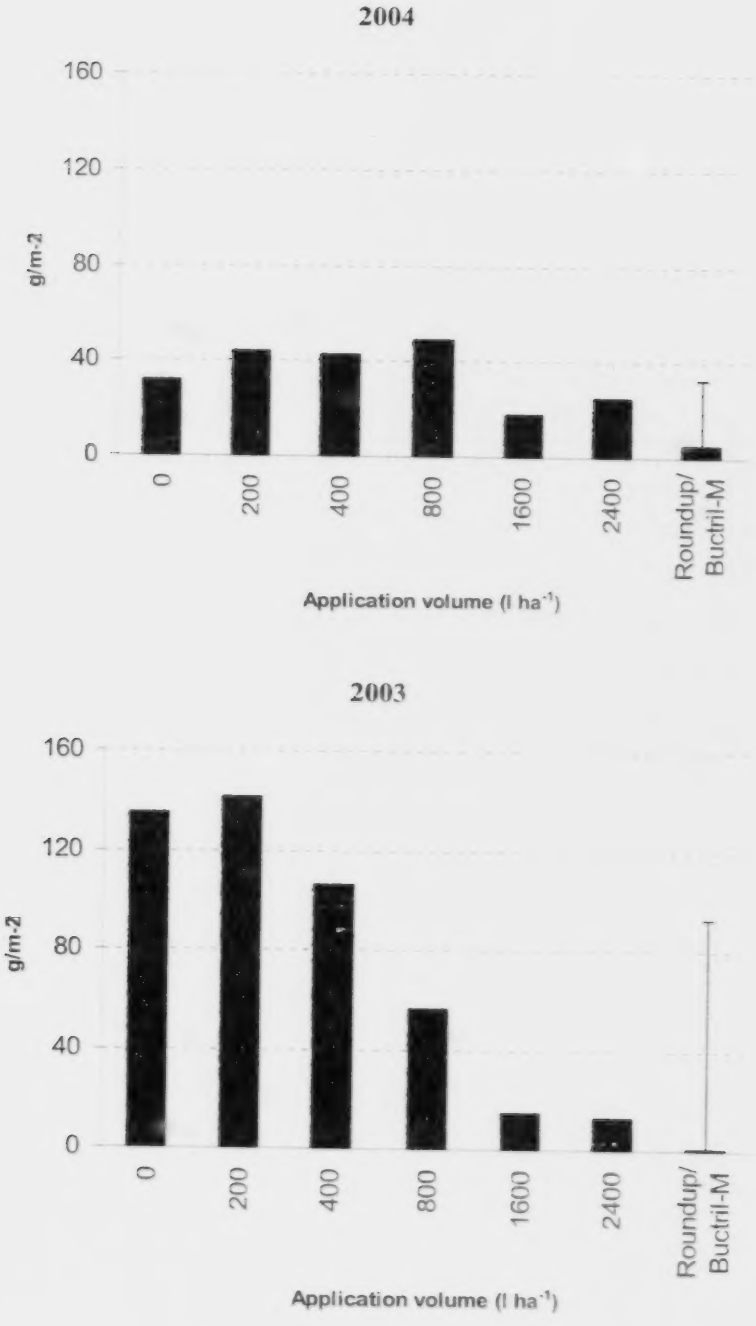


Figure 5: Effect of pre-seed and post-emergence vinegar (10% acetic acid) application on weed biomass of spring wheat at Scott in 2004 (above) and 2003 (below). Error bar represents the $LSD_{0.05}$.

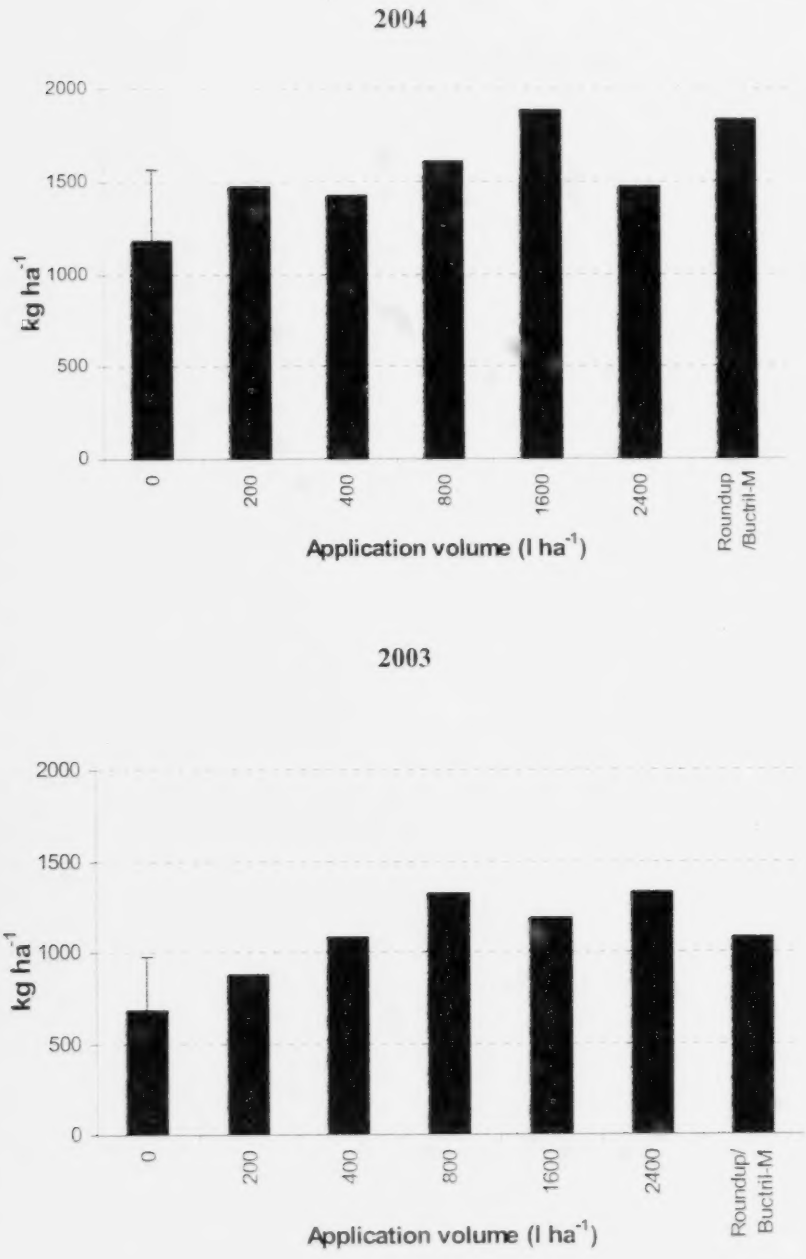


Figure 6. Effect of pre-seed and post-emergence vinegar (10% acetic acid) application on yield of spring wheat at Scott in 2004 (above) and 2003 (below). Error bar represents the $LSD_{0.05}$.

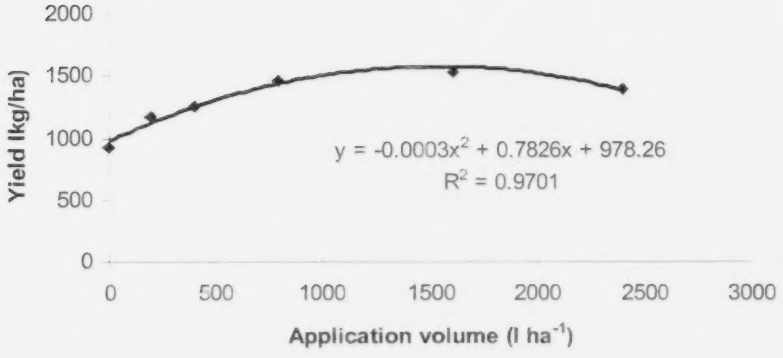


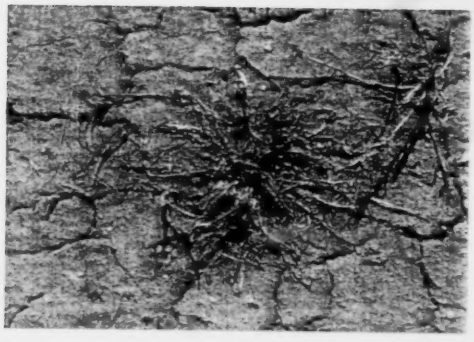
Figure 7: Relationship between 10% acetic acid application volume and spring wheat yield (Mean of two site-years). Scott, SK. 2003-04.

Conclusions

Vinegar at a 10% acetic acid concentration was able to control weeds and increase wheat yields. Application volumes of ∃ 1600 L ha^{-1} were required to provide weed control comparable to the commercial standards; however wheat yields were maximized at a rate of 1300 to 1400 L ha^{-1}. The cost of the product used in this study was $160.00 for 200 liters (80 cents/ liter), therefore, it does not appear to be a cost-effective method of controlling broadleaf weeds in spring wheat crops.

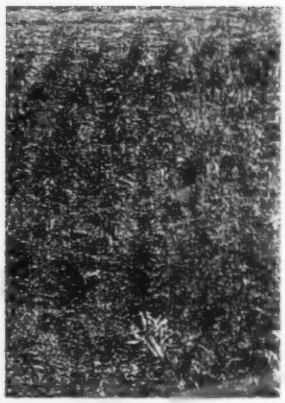
Photos from Scott Field Study, 2003

Application of 2400 l ha^{-1} vinegar in field.
Note soil wetting.

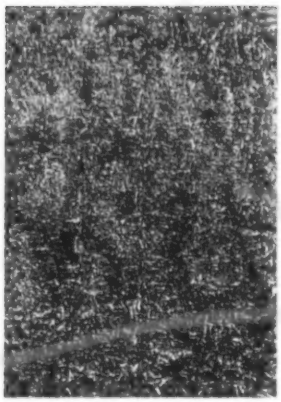


2400 l ha^{-1} applied to dandelion pre-seed.
Outer leaves are burned but regrowth occurred within
2 to 3 weeks.

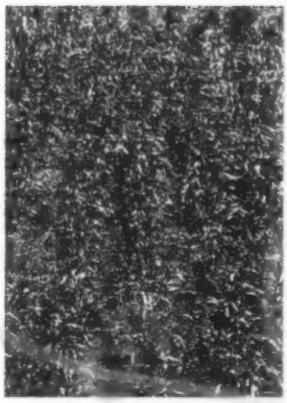
Photos of In-crop Weed Control at Scott (photos taken June 30, 2003



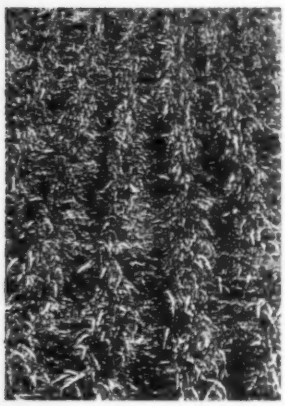
Untreated



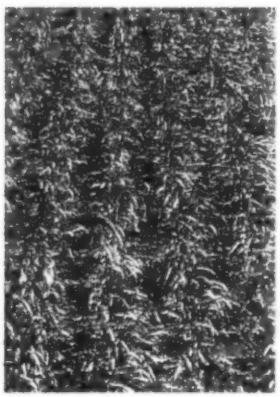
200 L / ha



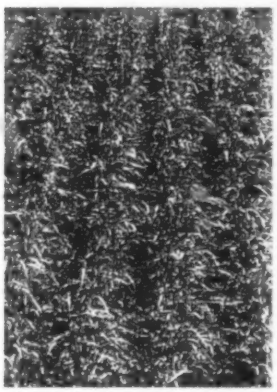
400 L/ha



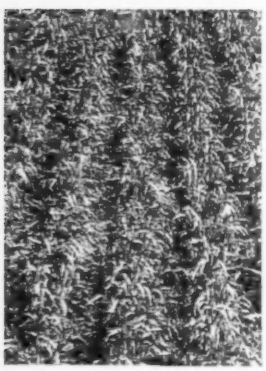
800 L/ha



1600 L/ha



2400 L/ha



Roundup/ Buctril- M

Tolerance and Weed Control in Flax with Acetic Acid
(Field study 2004, Kernen Research Farm)

Background

- Demand and prices for organically grown flax is currently high. Field studies have indicated that spring wheat will tolerate acetic acid and broadleaf weeds can be controlled. However, the application volume is high and is not economic in organic spring wheat production. It was hypothesized that there may be some economic potential for acetic acid in poorly competitive, high value organic flax production.

Materials and Methods

- Experiment was conducted at the Kernen Research Farm at Saskatoon, SK.
- AC Watson flax was seeded on May 25, 2004 at a rate of 35 kg/ha.
- Post-emergence treatments: Vinegar (10% acetic acid) at 0, 200, 400, 800, 1600 and 2400 L ha^{-1} and bromoxynil-MCPA at 560 g ai ha^{-1} (commercial standard). Application timing: flax - 5 to 10 cm in height. Grass weeds were controlled with clethodim at 47 g ai ha^{-1}.
- Weeds present included stinkweed, wild mustard, and wild buckwheat.
- Visual ratings for tolerance and weed control were done 4 and 17 DAT. Crop yield data was also collected.

Results

Flax tolerance

- Application volumes of 800 L ha^{-1} or higher resulted in unacceptable injury in flax (Table 1).

Weed control

- Application volumes of 1600 L ha^{-1} or higher resulted in greater than 80% control of wild mustard (Fig. 1). Application volumes of 1600 L ha^{-1} or higher provided about 75% control of stinkweed and did not provide satisfactory long-term control of wild buckwheat (Fig. 1).

Flax yield

- Application volumes of 800 L ha^{-1} or higher resulted in statistically lower yields than the check or the industry standard (Fig. 2).

Conclusions

- Flax did not tolerate acetic acid at application volumes that were required to provide satisfactory weed control.

Table 1: Effect of post-emergence vinegar applications (10% acetic acid concentration) on tolerance of flax. Saskatoon, 2004.

Application	Flax Visual Injury (%) 4 DAT	Flax Visual Injury (%) 17 DAT
Untreated	0	0
Vinegar 200 l ha^{-1}	2	0
Vinegar 400 l ha^{-1}	6	0
Vinegar 800 l ha^{-1}	25	15
Vinegar 1600 l ha^{-1}	85	60
Vinegar 2400 l ha^{-1}	92	82
Buctril-M 560 g ai ha^{-1}	7	0

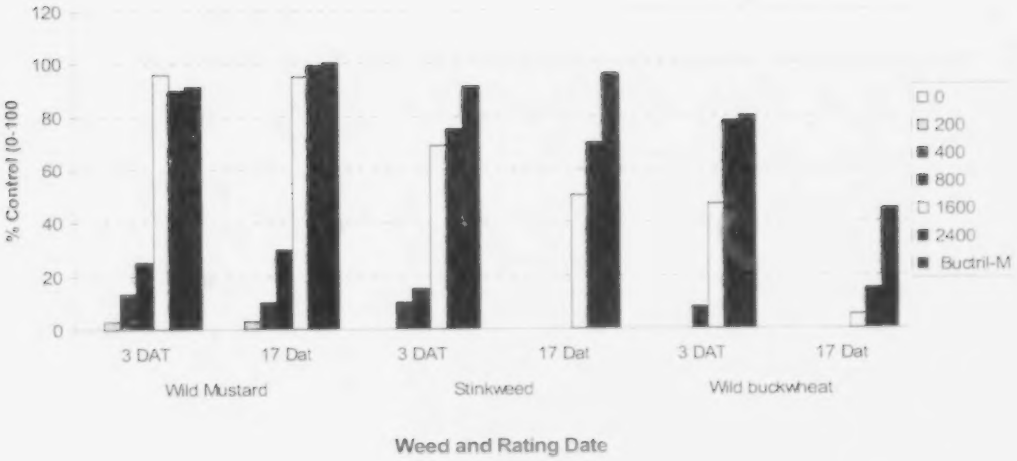


Figure 1: Visual control ratings of wild mustard, stinkweed, and wild buckwheat with 10% acetic acid. Saskatoon, SK. 2004.

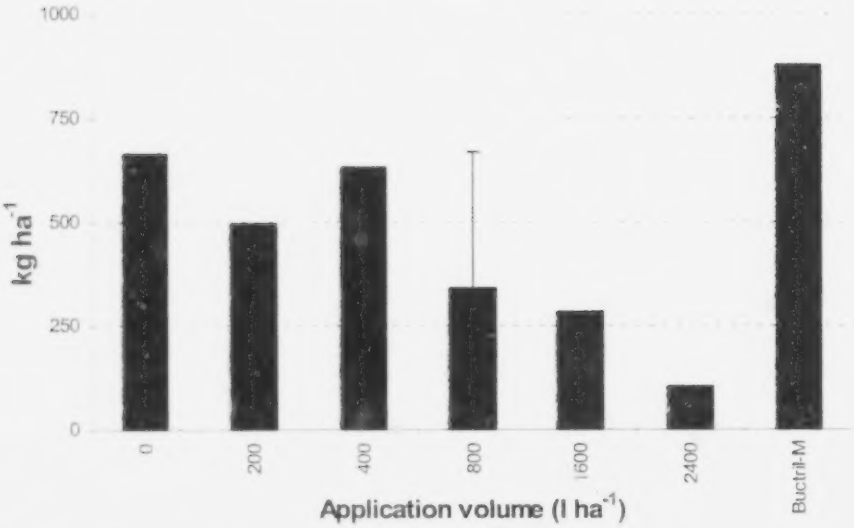


Fig. 2: Effect of application volume of 10% acetic acid on yield of flax. Saskatoon. 2004.

Tolerance of Tame Oat to Acetic acid
(Field Study 2003, Kernen Research Farm)

Materials and Methods

- The study area was relatively weed-free.
- Post-emergence treatments: Vinegar (10% acetic acid) at 0, 200, 400, 800, 1600 and 2400 L ha^{-1} and bromoxynil-MCPA at 560 g ai ha^{-1} (commercial standard). Application timing: oat - 1 to 2 leaf stage.
- Visual ratings of the post-emergence application were done 25 and 40 DAT. Crop yield data was also collected.

Results

- Results are presented in Table 1.
- Tame oat exhibited unacceptable visual injury at vinegar application volumes greater than 1600 l ha^{-1} at both 25 and 40 DAT. Unlike the spring wheat study, visual injury symptoms did not disappear after time.
- Yields of oat declined at application volumes of 800 to 1600 l ha^{-1} indicating that oat is not tolerant to high application volumes of vinegar in the field.

Table 1: Effect of post-emergence vinegar applications (10% acetic acid concentration) on tolerance and yield of tame oat. Saskatoon. 2003.

Application	Oat Visual Injury (%) 25 DAT	Oat Visual Injury (%) 40 DAT	Oat Yield (kg ha^{-1})
Untreated	0	0	3190 ab
Vinegar 200 l ha^{-1}	1	0	3348 a
Vinegar 400 l ha^{-1}	6	1	3286 a
Vinegar 800 l ha^{-1}	15	6	2987 bc
Vinegar 1600 l ha^{-1}	38	26	2736 d
Vinegar 2400 l ha^{-1}	48	31	2820 cd
Buctril-M 560 g ai ha^{-1}	0	1	3248 a
CV			4.7
$LSD_{0.05}$			216

Conclusions

Under relatively weed-free conditions, vinegar application resulted in unacceptable crop injury and reduced tame oat yields at application volumes greater than 800 l ha^{-1}. It is not known whether the benefit of the weed control would offset the yield reduction if the experiment was conducted in weedy conditions.

Efficacy of Pelargonic Acid as a Non-Selective Herbicide
(Field Study 2004, AAFC, Scott and Saskatoon)

Background

- Pelargonic acid is sold under the trade name Scythe® and is sold in the United States as a non-selective bio-herbicide.
- Greenhouse studies conducted at Agriculture and Agri-Food Canada in Saskatoon indicated that pelargonic acid may have potential as a non-selective herbicide.

Objective

- To evaluate the potential of pelargonic acid as a non-selective herbicide in organic production.

Materials and Methods

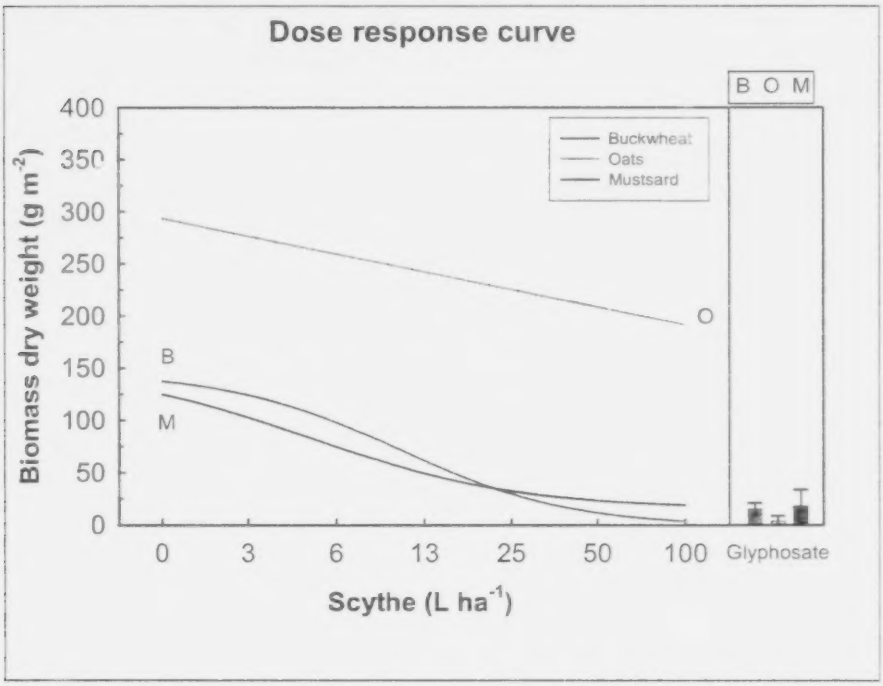
- Indicator species (tame oat, tame buckwheat and oriental mustard) were seeded in a split-block design with varying rates of pelargonic acid applied to them in a randomized complete block. Plots were replicated 4 times.
- The crops were seeded at recommended seeding rates on June 16 and June 10 in Scott and Saskatoon, respectively.
- Rates of pelargonic acid included 3.1%, 6.3%, 12.5%, 25%, 50% and 100% as well as an untreated check and a glyphosate check of 450 g ai ha^{-1}. The label rate in the United States is a 3 to 6% (3 to 6 L ha^{-1}) solution. The herbicides were applied in application volumes of 100 L ha^{-1}. Application was made when the tame buckwheat was in the 1-2 leaf stage, oats in the 3-4 leaf stage, and mustard in the cotyledon-1 leaf stage (Saskatoon). At Scott, tame buckwheat was in 2-3 leaf stage, oats in the 4 leaf stage, and mustard in the 1-2 leaf stage.
- Data collected included visual control ratings at 3, 7 and 14 DAA and plant biomass sampling 14-21 DAA. At Scott, plant fresh weight was measured while at Saskatoon, dry weights were measured.
- Data was subjected to dose response analysis and EC^{50} was calculated.

Results

- At both Scott and Saskatoon, visual control or biomass reduction of tame oat did not fit a typical dose response curve (Fig. 1). The maximum biomass reduction at 100% concentration (100 L ha^{-1}) was 54 and 53% at Saskatoon and Scott, respectively. Unlike the greenhouse studies, pelargonic acid did not control oats in the field.
- The EC_{50} for tame buckwheat (based on biomass reduction) was 4.72 L ha^{-1} and 10.15 L ha^{-1} for Scott and Saskatoon, respectively. A rate of 25 L ha^{-1} resulted in an 87 and 75% reduction in buckwheat biomass at Scott and Saskatoon, respectively. This is 4 to 8 X the recommended label rate. At both sites, 50 L ha^{-1} provided similar biomass reductions as glyphosate.
- The EC_{50} for oriental mustard biomass reduction was 12.2 L ha^{-1} at Scott (2 to 4 X label rate). At Saskatoon, mustard biomass reduction did not fit a typical dose response curve; however, a rate of 3.1 L ha^{-1} reduced biomass by 59%. A rate of 25 L ha^{-1} resulted in approximately a 70% reduction in mustard biomass at both locations. A rate of 50 L ha^{-1} resulted in 85 to 90% reduction in mustard biomass. These rates are significantly higher than the label rate.

Conclusions

- Based on US prices, pelargonic acid would retail for about $13.00 Canadian per liter. Rates of > 25 L ha^{-1} were required to provide similar control as glyphosate on some broadleaf species. Therefore, the cost would range from $325.00 to $650.00 per ha ($130.00 to $260.00 /acre). Therefore, pelargonic acid does not appear to be a cost-effective solution.
- Unlike greenhouse studies, pelargonic acid did not control tame oat.



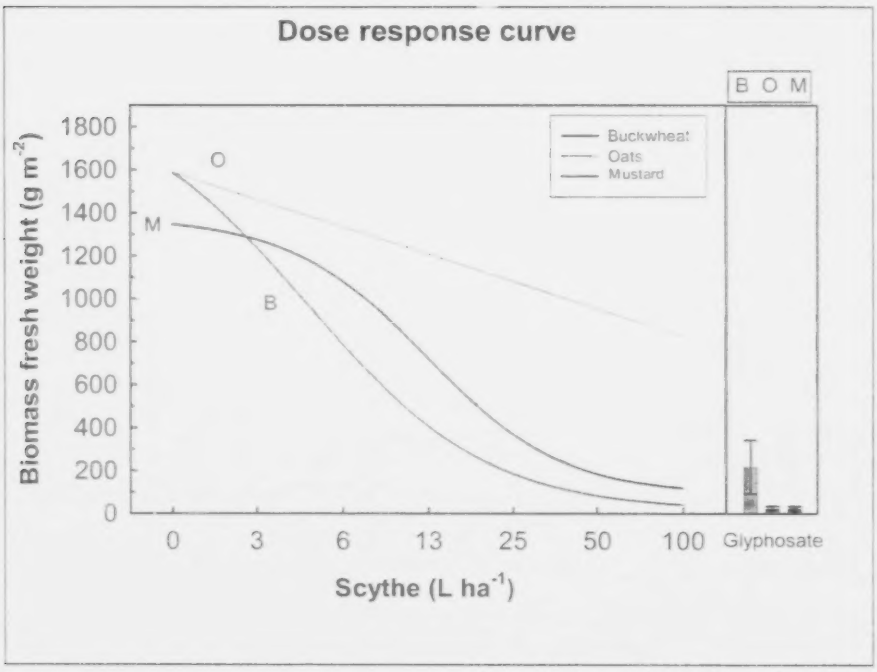


Figure 1: Dose response of tame oat, tame buckwheat, and oriental mustard to rates of pelargonic acid (Scythe®). Field studies at Saskatoon (above) and Scott (below), 2004.

Acknowledgements

Financial support was provided by the Saskatchewan Agricultural Development Fund and AAFC. In-kind contributions were provided by Dow AgroSciences and Reinhart Foods, Saskatoon. The technical assistance of Herb Schell, Cindy Gampe, Curtis Sieben, Chris Gilchrist, Gerry Stuber, and Terri It, is much appreciated.